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Unlocking the power potential of wastewater

A US Department of Energy project will use produced water from oil and gas wells for low-temperature geothermal application.

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Many US oil and gas wells produce hot water as well as hydrocarbons. These wells—which, in general, produce fluids at temperatures below 220°F—have been estimated to be capable of generating as much as 5,000 MW of power. The Rocky Mountain Oilfield Testing Center (RMOTC) recently partnered with Ormat Nevada Inc. to test the concept of using oilfield wastewater to power field production equipment.

The test will be performed beginning early in 2008 at Teapot Dome Oilfield, also known as Naval Petroleum Reserve No. 3 (NPR-3), located about 35 mi north of Casper, Wyoming. NPR-3 is operated by the US Department of Energy (DOE) as both a producing oil field and a test site for new and developing oil and gas, and renewable, energy-related technologies.

THE PROJECT

In January 2007, Reno-based Ormat, which develops and operates geothermal power plants in three states and internationally, entered into a Cooperative Research and Development Agreement (CRADA) with the DOE. The purpose of the project is to validate the premise that a binary geothermal power-generation system using hot water produced by an oil field can reliably generate commercial electricity. The unit to be used is similar to the 250-kW Ormat Energy Converter (OEC) unit that has been producing electricity from 210°F geothermal water at an Austrian resort for more than 6 yr, Fig. 1. Similar units have also been in continuous commercial operation since the 1980s in Nevada and Thailand.

The power system, which is set to undergo testing in early 2008, is a commercial, air-cooled, skid-mounted, standard Organic Rankine Cycle (ORC) power plant. Ormat will supply the unit, and RMOTC will install and operate the facility for a 12-mo test period—together about a $1 million investment. The binary power unit brings produced hot water through pipelines to a heat exchanger in the power system. In the heat exchanger, the geothermal fluid heats and vaporizes a secondary working fluid, which is typically an organic fluid with a low boiling point.

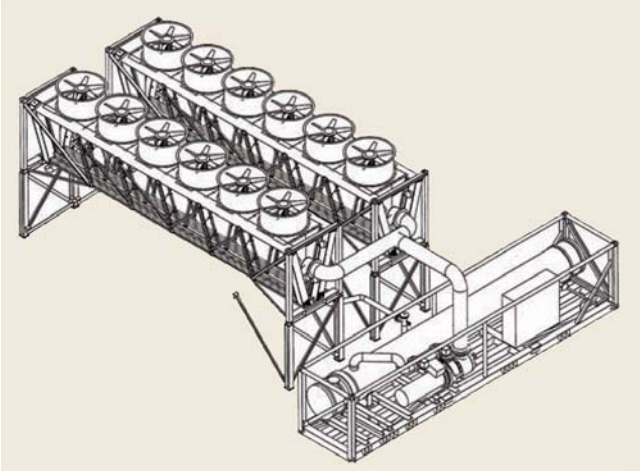

Fig. 1. The proposed geothermal power unit is an air-cooled, skid-mounted, standard Organic Rankine Cycle (ORC) plant.

The organic vapors drive a turbine that powers a generator, and then are condensed for recycle into the heat exchanger, completing the cycle within a closed system. The cooled geothermal fluid is reinjected into the reservoir or discharged. For the RMOTC plant, the circulating fluid will be isopentane.

The unit that will be used at RMOTC has been field-proven in other situations, but has never been used in an oil field. In the past 25 yr, Ormat has designed and supplied more than 900 MW of geothermal power plants, most of which are still in operation. Initially focused on low-temperature resources only, the technology has expanded to a wide range of resource conditions, including up to 437°F in Hawaii, with applications that include power units for onsite use as low as 200 kW and complete central station geothermal plants up to 125 MW.

GEOTHERMAL POTENTIAL AT NPR-3

Two formations at NPR-3 produce sufficient hot water for the generation of low-temperature geothermal energy. The present potential of the Tensleep and Madison production sites is shown in Fig. 2. The average production temperature for the Tensleep zone is 190°F; for the Madison zone it is 200°F. Early projections indicate that with minor work on present wells, the rate for the combined Tensleep and Madison produced water would be between 126,000 and 210,000 bwpd. Table 1 gives the breakdown of the projected production for individual wells. There is also potential to drill additional Tensleep and Madison wells.

The produced water from the Tensleep formation is projected to produce 180 kW of gross power. When the Madison produced water is included with potential increases in Tensleep

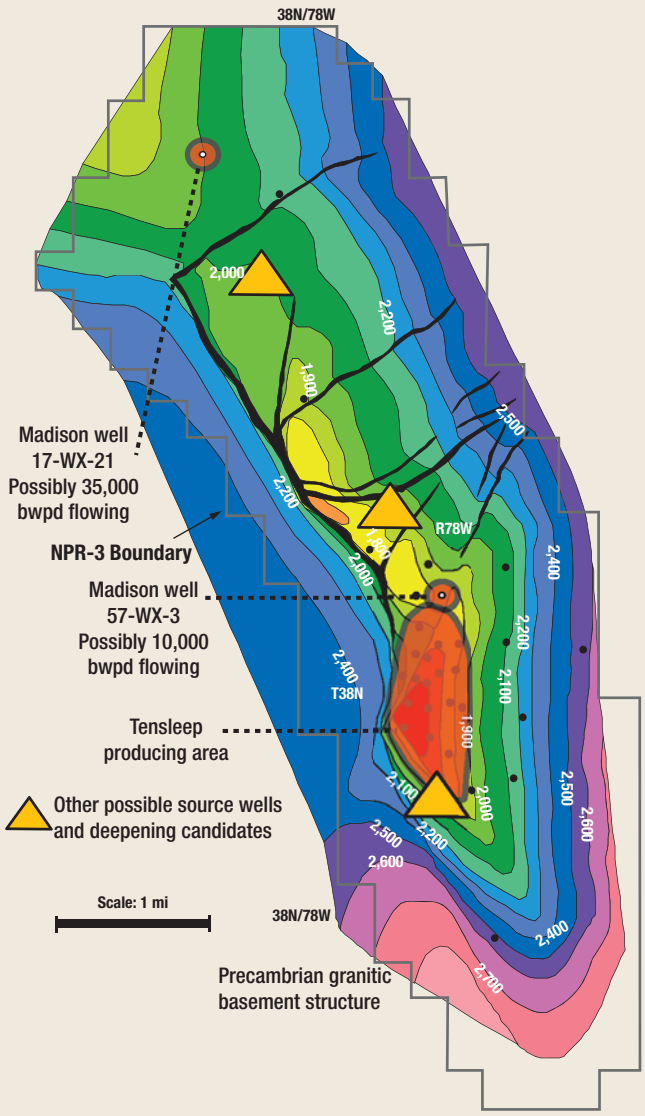

Fig. 2. Potential geothermal supply wells at Naval Petroleum Reserve No. 3 oil field.

TABLE 1. NPR-3 projected geothermal potential

Well	Rate, 1,000 bwpd		Comments
	Low	High	
Madison zone			
17-WX-21	20	25	Flowing
41-2-X-3	6	12	Needs deepening
61-2-X-15	6	12	Needs deepening
57-WX-3	2	6	Flowing
Tensleep zone			
17-WX-21	4	10	Needs perforating
41-2-X-3	1	3	Flowing
48-X-28	2	6	Flowing
61-2-X-15	2	6	Flowing
Total new flowing production	43	80	
Total new pumping production	86	160	Assumed double the flowing rate
Total of 12 current Section 10 Tensleep wells	40	50	Pumping
All potential production	126	210	All on pump

Fig. 3. Currently, hot water from the wells is a waste stream that is treated and cooled through a series of ponds before discharge. The power system would harness the water's heat before it reached the cooling ponds.

production, the gross power potential would be in the range of 540–900 kW. Currently, the hot water is a waste stream and is sent through a series of treatment ponds and then discharged into an adjacent stream, Fig. 3. The power system will allow the water's heat to be harnessed before it reaches the ponds. The electricity generated from the Tensleep wells' produced water will be used to power field production equipment. The ORC power unit will be connected to the field electrical system, and the produced energy will be metered and monitored for reliability and quality.

The aquifers in both the Tensleep and Madison formations are continuously recharged from the mountains to the west, Fig. 4. As shown, the Tensleep and Madison are interconnected by a series of fractures to the underlying formations and the basement rock.

Produced water characteristics. The produced waters from the Tensleep and Madison formations are of relatively high quality. The Tensleep water contains 3,100 mg/L of total dissolved solids, and the Madison has 2,900 mg/L; the only contaminant that approaches the surface discharge limit is chlorine. The Tensleep water for geothermal power production will come directly from the oil-water separators. This water contains about 150 ppm of oil and passes through a series of biotreatment ponds prior to discharge in the adjacent drainage. The Madison is a non-oil-bearing formation at Teapot Dome and therefore does not require treatment before discharge.

Because both of these water streams are of high quality, they should not present a fouling problem in the geothermal unit's heat exchangers as the water temperature decreases. Heat exchangers used with oilfield-produced waters having higher salinity, more carbonate or other minerals and higher organic loading will have to address the fouling and scaling issues. The use of the entire production stream before the oil-water separator will provide the greatest geothermal potential; again, fouling questions will need to be addressed. This configuration, with geothermal power production before the separator, is being considered for the RMOTC project, provided time permits and all parties agree.

POWER GENERATION CAPACITY

The power unit is scheduled for delivery in January 2008. The resource is expected to enter the power unit at the relatively low temperature of 170°F. At the design ambient tem-

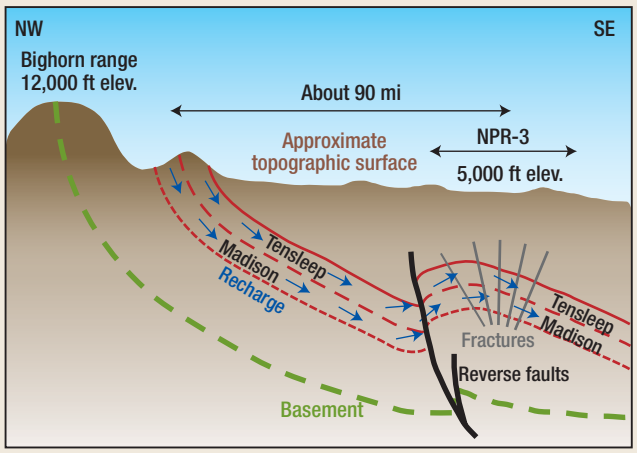

Fig. 4. Mountains to the west provide continuous recharge for the aquifers in the Tensleep and Madison formations.

TABLE 2. Projected power system performance at design temperature

Flowrate	292 t/hr
Inlet temperature	170°F
Outlet temperature	152°F
Ambient temperature	50°F
Generator gross power	180 kW
Net power output	132 kW

perature of 50°F, the plant is anticipated to produce a net 132 kW, Table 2.

If the resource temperature can be increased to 190°F, the net output may be increased from 180 kW to about 230 kW. This analysis and the future measured performance data are expected to demonstrate the viability of the concept.

CONCLUSION

Harnessing the available hot water produced during oil production to power the oil field could potentially lead to more economical access to reserves, especially in stripper fields such as NPR-3. The use of field-proven and time-tested technologies to test geothermal application in the oil field builds confidence that this clean, renewable source could become commonplace in future oil fields. **WO**

THE AUTHORS

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